A Study of Engine Performance and Emission Characteristics of Mahua Biodiesel and Its Blends

N. Acharya[1], P. Nanda [2], S. Panda[3]

Abstract - Transport sector is the life line of Indian economy. Around 70% of total diesel consumption of the country is consumed by transport sector and its exhaust emission is a major source of air pollution. So to resolve the energy and environmental crisis, biodiesel is an alternative source of fuel which is prepared from renewable source like vegetable oil. Biodiesel from non-edible vegetable sources oil is a good option as these are plentily available in Indian forest. Mahua is one of the non-edible vegetable oil plants which are abundantly found in India and its oil content is around 35- 45%. In this paper the suitability of mahua biodiesel as fuel in diesel engine has been studied and different aspects like physico-chemical properties, engine performance and emission characteristics of mahua biodiesel and its blends has been carried out in a diesel engine. It has been found that mahua biodiesel can be used as an alternative fuel in diesel engine in pure or blended form and can help to solve the energy and environmental crisis.

Index Terms - Air pollution, Renewable, Vegetable oil, Mahua, Fatty acid, Transesterification, Biodiesel

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1 Introduction

Air pollution is a major concern for every nation of the world. The exhaust emission from vehicles is a major source of air pollution and the cause of different health problems. It contains different harmful gases like Carbon monoxide (CO), Hydrocarbon (HC), Oxides of Nitroge (NOx) which affects the human health adversely. The demand and supply gap of the petro diesel is increasing day by day which is directly affecting the economy of country. The source of diesel is also limited and will be exhausted within a short period as the consumption rate is in increasing trend due to more energy requirement[1]. So there is a need of liquid fuel which can replace the petro diesel. Presently one of the alternatives of petro diesel is vegetable oil, which has nearly equal calorific value but cannot be used directly due to its higher viscosity. Its use in diesel engine affects the engine operation and may be the cause of premature failure of engine components. But vegetable oil can be used in engine after reduction of viscosity by trans-esterification process. The trans-esterified vegetable oil is called biodiesel. There are around 350 nos of oil bearing plants available in nature [2]. Some of these are edible but its use as biodiesel will cause crisis of food. So attention has been shifted towards non-edible vegetable oils. The mahua (Madhuca indica) tree, widely available in Indian forest produces seeds that contains around 35- 45% oil by weight which is non-edible and its annual availability is around 60MT [3]. The mahua oil can be used as feedstock for preparation of biodiesel. In this paper the suitability of mahua biodiesel as fuel in diesel engine has been studied and different aspects like physico-chemical properties, engine performance and emission characteristics of mahua biodiesel and its blends has been carried out in a diesel engine.

Padhi and Singh[4] found the optimized parameters for biodiesel production from mahua oil and concluded that the mahua biodiesel is cost effective and viable alternative fuel for diesel engine. Puhan et al.[5] studied the engine performance and emission parameter of mahua biodiesel and petro diesel in a diesel engine and reported for increase in brake specific fuel consumption (BSFC) and reduction in brake thermal efficiency (BTE) than that of petro diesel. It is also reported by authors regarding drop in exhaust emission components. Saravnan et al.[6] also studied the performance of mahua biodiesel and petro diesel in a single cylinder diesel engine and observed that thermal efficiency is at par with that of petro diesel and there is a significant drop in exhaust emission. Raheman and Ghadge [7] studied the performance of mahua biodiesel and its blend with mineral diesel and reported about increase in BSFC and lowering of CO and HC but increase in NOx emission. They also recommended the 20% biodiesel can be blended safely without affecting the engine power. Prajapati et al.[8] studied the suitability of transesterified mahua oil as diesel fuel. Acharya et al. [9] developed a model using an Artificial Neural Network (ANN) to predict the different output parameters of engines like BTE, BSFC, emission of CO, HC, NOx and smoke.

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2 Mahua Tree

Mahua tree is an Indian origin, large deciduous tree growing widely in dry tropical and sub-tropical region. It is found in different part of the country like Odissa, Chhattisgarh, Jharkhand, Bihar, Uttar Pradesh, West Bengal and Maharashtra. It is a fast growing tree and grows up to 20-25ft of height. It is a very important tree for tribal people for its seed and flower. Flowering occurs around the month of February to April and fruits ripen in the month of May to July. The tree starts bearing fruits after 10th year of plantation. The Fig.1 depicts mahua tree, flower and seed.

Mahua Tree Mahua Flower Mahua Seed

Fig.1. Mahua tree, flower and seed

3 Use of Mahua oil

The mahua oil has different application. It is used for manufacturing of soap, grease and alcohol. The tribal community uses it in cooking. Mahua cake has been used as pesticide, bio fertilizer or cattle food. Different parts of mahua tree also have medical application. Flowers are used for relieving lungs related problems like cough, asthma and TB, eye problem, heart-disease, blood related diseases, tonsillitis and internal worms. The bark is also used for relieving itching, healing wounds, fracture and snake bites. The tree is well distributed in India, particularly in deciduous forest. Madhya Pradesh and Odisha accounts for nearly 80% of mahua tree in India. The different fatty acid profile of mahua oil is presented in Table 1. The mahua oil has an acid value as low as 3.5 and contains 21% free fatty acid (FFA).

TABLE 1

FATTY ACID COMPOSITION OF MAHUA OIL

Fatty acid	Structure	Value (wt %)
Oleic	18:1	41-51
Palmitic	16:0	16-28.2
Steric	18:0	20-25.1
Linoic	18:3	8.9-13.7
Arachadic	20:0	0-3.3

4 Biodiesel preparations

The mahua oil has been collected from local source and filtered to remove any impurities. Then biodiesel has been prepared by using trans-esterification process. Initially the mahua oil has been warmed up to a temperature of about 60-650C and methanol (in the ratio of 1:6) and sodium hydroxide (3.5gm/litre of raw oil) have been added to it. In this process sodium hydroxide is used as catalyst. Then total mixture have been blended for proper mixing and kept undisturbed for 48 hours. After completion of the reaction, whole mixture gets separated into two distinct layers. The upper layer of the mixture is methyl ester and lower layer is glycerol. Then the upper layer is gently decanted to another container and warm distilled water around 10% of the volume of methyl ester has been added to remove the catalyst if any. The same is allowed to settle for another 24 hours and after settling the top layer is gently decanted leaving the impurities at bottom. The sample of biodiesel has been collected and sent to laboratory for measurement of different properties. The different physico-chemical properties of biodiesels have been measured as per ASTM- D6741 standard and presented in Table 2. The cetane number (CN) is calculated as per eq.1 [10].

5 Characterization of Mahua oil and Biodiesel

A comparison of different properties of mahua oil, mahua mahua biodiesel prepared by transesterification process has been presented in Table 2 .Different standards for biodiesel like ASTM- D6751, EN-14214 and IS-15607 has been also been presented in Table 2 also.

TABLE 2.
COMPARISION OF PROPERTIES OF MAHUA OIL MAHUA BIODIESELS WITH MINERAL DIESEL AND DIFFERENT STANDARDS

Properties	Mahua oil	Mahua biodiesel	Petro Diesel	ASTM-D6751	EN-14214	IS-15607
Density at 150C (Kg/m3)	924	882	824		860-900	860-900
Kinematic Viscosity at 400C (mm2/Sec)	39	4.2	2.30	1.9-6	3.5-5	2.5-6
Flash point (0C)	230	170	53	>130	>101	>120
Calorific Value (MJ/Kg)	32	38.5	42	-	-	-
Cetane Number	--	57	51	47 min	51 min	51 min

$$CN = \left[46.3 + \left(\frac{5458}{SN}\right) - (0.225 \times IV)\right] \quad (1)$$

Where 'SN' is the saponification value and 'IV' is the iodine values which are and determined from the equation (2) and (3).

$$SN = SUM\left(\frac{560 \times Ai}{Mwi}\right) \quad (2)$$

$$IV = SUM\left(\frac{254 \times D \times Ai}{Mwi}\right) \quad (3)$$

The terms 'Ai' represents the percentage of each component, 'Mw' represents the molecular mass of each component and 'D' represents number of double bond.

6 Results and Discussion

The engine performance of mahua biodiesel and its blends has been carried out in a diesel engine fitted with exhaust gas analyzer and smoke meter. For this purpose initially the engine has been run by petro diesel (B0) and readings have been taken in different loads (25%, 50%, 75% and 100%). Then the engine has been run by blends of biodiesel and pure biodiesel (B10, B20, B30 and B100). The notation Bn represents blends of biodiesel and petro diesel. The term'n' represents percentage of biodiesel in the mixture of petro diesel and biodiesel.

In this section the experimental results have been presented as graph between variation of load on the engine and the different performance parameters.

6.1 Engine Performance

The performance of an engine is evaluated by its brake thermal efficiency and fuel consumption per unit brake power output.

6.1.1 Brake Thermal Efficiency (BTE)

The Brake Thermal Efficiency (BTE) represents the percentage of fuel energy converted to useful energy. The variation of BTE with variation of load for mahua biodiesels and its blends with mineral diesel is shown in Fig 2. It is observed that the BTE of the fuels increase with increase in load and at full load the BTE of mahua biodiesel is 7% lower than that of mineral diesel. It is also observed from graph that the BTE of blends of biodiesel are nearer to that of petro diesel. This is attributed to lower percentage of biodiesel in the mixture does not affect the calorific value and lubricity of biodiesel helps to reduce the friction and BTE is un-affected.

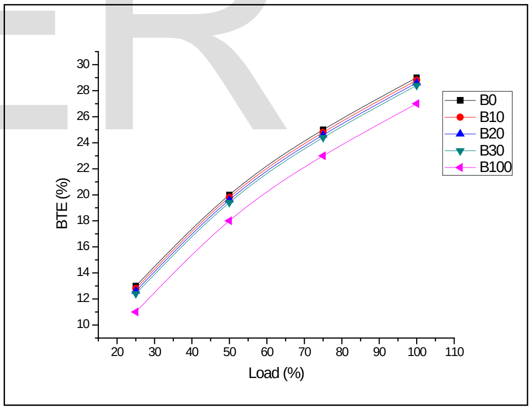

Fig.2. Variations of BTE with load

6.1.2 Brake Specific Fuel Consumption (BSFC)

The variation of BSFC with variation of load for biodiesels and its blends and mineral diesel is shown in Fig. 3. It is observed that the BSFC of biodiesel and its blends decreases with increase in load and at full load the BSFC of mahua biodiesel is 22 % higher than that of mineral diesel. The higher BSFC of the engine using biodiesels is due to its lower calorific value and higher viscosity. Due to the higher viscosity, the fuel does not atomize properly and fuel-air mixture is less homogeneous as compared to that of petro diesel which results in improper combustion, causing higher BSFC for same power output as compared to petro diesel. It is also observed that at lower blends (up to B20) the BSFC is nearer to that of petro diese

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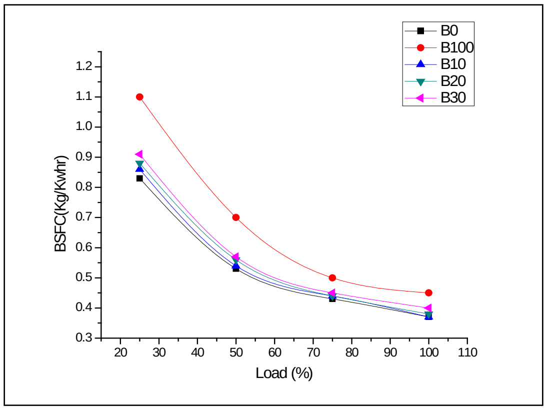

Fig.3. Variations of BSFC with load

6.2 Emission Characteristics

In this section different emission characteristics like emission of carbon monoxide, hydrocarbon, oxides of nitrogen, smoke intensity of biodiesels and petro diesel have been measured and plotted as graph against variation of engine load.

6.2.1 Carbon Monoxide (CO)

The variation of emission of CO with variation of load for the mahua biodiesel and its blends and petro diesel is depicted in Fig.4. It is clearly observed for all the fuels that CO increases with increase in load. But it is also observed that in all loading conditions the emission of CO is lower for biodiesels as compared to that of petro diesel. This is attributed to the presence of higher amount of oxygen in biodiesel than petro diesel which results in better combustion and lower CO emission [11]. At full load, there is around 13% reduction in emission of CO for mahua biodiesel than that of petro diesel. It is also observed that there is reduction of emission of CO for blends of biodiesel also.

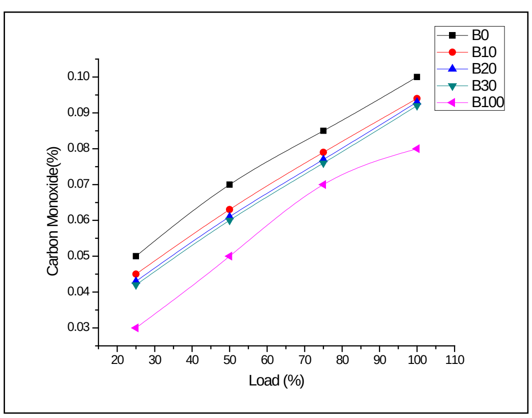

Fig.4. Variation of Carbon Monoxide with load

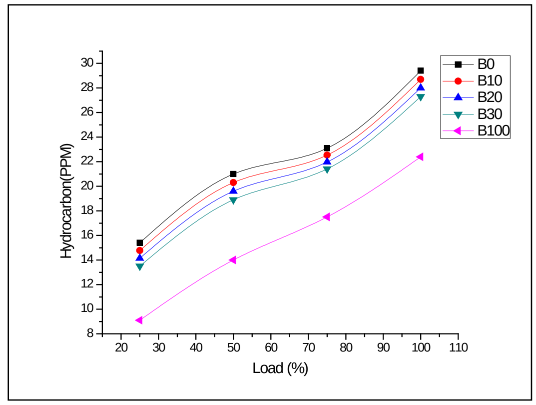

Fig. 5. Variation of HC with load

6.2.2 Hydrocarbon (HC)

The variation of emission of HC with variation of load for mahua biodiesels and its blends and petro diesel is depicted in Fig.5. It is clearly observed that for all the fuels emission of HC increases with increase in load. But in all loading conditions, there is a reduction of emission of HC for mahua biodiesel and its blends as compared to emission from petro diesel. At full load the emission of HC for mahua biodiesel is 24% lower than that of petro diesel.

5.2.3 Oxides of Nitrogen (NOx)

The NOx formation depends upon different factors like temperature of the cylinder and rate of combustion. The variation of emission of NOx with variation of load for mahua biodiesel and its blends and petro diesel is depicted in Fig. 6. It is observed that emission of NOx increase with increase in load for all the fuels and in all loading conditions emission of NOx for mahua biodiesel and its blends is higher as compared to that of petro diesel. At full load increase in emission of NOx for mahua biodiesel is 14% higher than that of petro diesel. As biodiesel contains more oxygen than petro-diesel the rate of combustion in case of biodiesel is higher resulting in more emission of NOx.

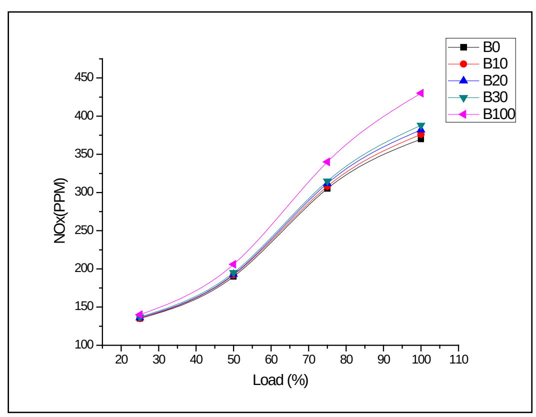

Fig. 6. Variation of NOx with load

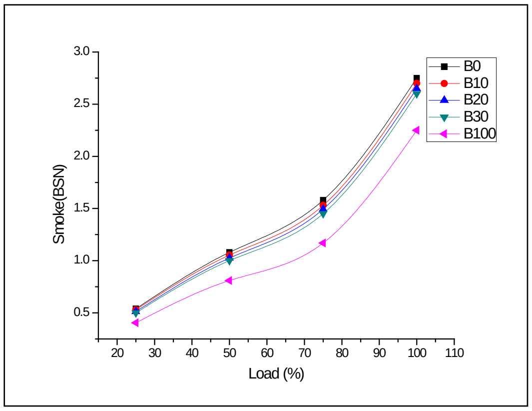

Fig. 7. Variation of Smoke with load

5.2.4 Smoke Intensity

Smoke is the visible product of an engine. The cause of excess smoke in an engine is either due to lean fuel-air mixture which is difficult to auto ignite or to support flame propagation, or too rich mixture to ignite the fuel [6]. The variation of emission of smoke with variation of load is depicted in Fig. 7. It is clearly observed that the smoke intensity increases with increase in load for mahua biodiesel and its blends and petro diesel. But in all loading conditions the smoke intensity of mahua biodiesel and its blends is lower than that of petro diesel. At full load the reduction of emission of smoke for mahua biodiesel is 18 % lower than that of petro diesel.

6 CONCLUSIONS

Mahua tree is widely available in forest region. Presently its flower and seeds are collected by local tribal community and used as food, medicine etc. Most of the seeds go waste in forest. So use of mahua seed as biodiesel will definitely help in reduction of dependency on petro diesel. From experimental result it is confirmed that the engine performance of blended mahua biodiesel (up to 30%) is nearer to that of petro diesel. The emission characteristics also reveal that there is a substantial reduction of CO, HC and smoke by using pure biodiesel which are major components in vehicular pollution. The blended biodiesel will also help in reduction of these components in exhaust emission. So use of mahua biodiesel as fuel either in pure or blended form will definitely mitigate energy and environmental crisis.

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